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Ricardian Equivalence and the Permanent Income Hypothesis: An Empirical Investigation

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Abstract

The Ricardian Equivalence Hypothesis (REH) states that the mix of debt and taxes in the financing of current government spending has no real impact because households see tha. a government deficit implies higher future tax liabilities. Government debt thus does not contribute to private lifetime wealth. As a result, private saving will rise by the full amount of the deficit in order to allow payment of future taxes.

This paper will test whether deficit financing affects consumption using Canadian data. The consumption model used to conduct the test is a generalized version of the permanent income hypothesis (PIH) first used by Atfield, Demery, and Duck (1992).

The results suggest that the generalized PIH model is consistent with the stylized facts for Canadian consumption, and that Ricardian Equivalence is a reasonable approximation of the response of private households to government deficits. It is possible, however, that the private savings offset to public dissaving is slightly less than 100 per cent. Many theoretical objections, such as the absence of full intergenerational altruism, lead to the view that absolute Ricardianism is improbable. The econometric evidence cannot distinguish between absolute and near Ricardian equivalence.

Résumé

D'après l'hypothèse de l'équivalence ricardienne, la source de financement des dépenses publiques courantes n'a pas de veritables effets car les ménages percoivent tout deficit publique comme une obligation fiscale future. La dette publique ne contribue donc pas a la richesse individuelle. Il en résulte que l'épargne privée augmentera à hauteur du plein montant du déficit, en prévision du paiement des impôts futurs.

Dans le présent document, l'auteur cherche à determiner si la source de financement du déficit affecte la consommation au Canada. Le modèle de consommation utilisé est une version généralisée de l'hypothèse du revenu permanent, que Atfield, Demery et Duck (1992) sont les premiers à avoir utilisée.

Selon les résultats, le modèle du revenu permanent généralisée est compatible avec les faits stylisés relatifs à la consommation canadienne, et l'équivalence ricardienne est une approximation raisonnable de la réaction des ménages face aux déficits publics. Il se peut toutefois que l'épargne privée tenant lieu de compensation de la désépargne publique soit légèrement inférieure à 100 pour cent. De nombreuses objections théoriques, comme l'absence d'altruisme intergénérationnel complet, sous-tendent l'opinion selon laquelle le ricardianisme absolu est improbable. La preuve économétrique ne permet pas de faire la distinction entre l'équivalence ricardienne absolue et approximative.

1 Introduction

To what extent is debt financing of a given level of government spending offset by higher private saving? An hypothesis first proposed by David Ricardo and formalized by Robert Barro states that the mix of debt and taxes in the financing of current government spending has no real impact because households see that a government deficit implies higher future tax liabilities and does not therefore affect their lifetime wealth. As a result, private saving rises by the amount of the deficit. If this so-called Ricardian Equivalence hypothesis (REH) were true, deficit financing would not affect total (private plus public) saving, leaving real interest rates and real incomes unchanged.

Various methodologies have been designed to test this hypothesis. Researchers have examined the relationship between fiscal variables and consumption, interest rates, exchange rates, the current account, and growth rates in order to find any possible link between the government sector's financial position and the private economy.

This paper will examine whether deficit financing affects aggregate saving. If REH holds, a higher deficit today, *ceteris paribus*, means that consumers understand that taxes will have to rise at some point in the future and increase their savings in order to be able to pay these liabilities. Consumption would therefore not respond to changes in taxes that lead to offsetting changes in borrowing. This is the hypothesis I will test.

The consumption model used to test REH is based on the permanent income hypothesis (PIH). The simplest PIH models have suffered from two problems: excess sensitivity and excess smoothness. Excess sensitivity, first discussed by Flavin (1981), is the fact that consumption responds more strongly to temporary changes in income than predicted by the simple PIH. Excess smoothness, described by Campbell and Deaton (1989), is the fact that consumption is smoother than permanent income, rather than being equally variable as implied by the simple PIH.

Campbell and Deaton suggested that this could stem from the existence of liquidity constrained agents, time-varying interest rates, and habit formation, that is, slow adjustment in the pattern of consumption due to inertia.

To carry out the test, I will adapt a consumption model with partial adjustment first used by Atfield, Demery, and Duck (1992). With partial adjustment, consumption will be less volatile than income and if there is correlation between actual and permanent income, consumption will exhibit excess sensitivity. This model can therefore reconcile PIH with the two stylized facts previously mentioned.

The paper is organized as follows: section 2 discusses theories of consumption and the permanent income hypothesis, section 3 provides the theoretical framework for Ricardian Equivalence, section 4 summarizes the evidence on Ricardian Equivalence, section 5 describes the construction of a government debt at market value series necessary for the test, section 6 provides the empirical results, and section 7 provides some conclusions.

2 The Permanent Income Hypothesis

The permanent income hypothesis (PIH) is a special formulation of the idea that consumers tend to smooth their consumption over time, with lifetime rather than current income being the basis for the consumption decision. Because of this smoothing, transitory changes in income have no effect on consumption in an infinite horizon setting. The PIH was first introduced by Friedman (1957), and in its simplest form can be stated as:

$$c_t = y_t^p \tag{1}$$

where c_t is consumption at time t and y_t^p is permanent income at time t. Consumption and permanent income would thus be equal in each and every period. Permanent income is defined as the annuity value of wealth (both human and non-human):

$$y_t^p = r\left[A_t + \sum_{i=0}^{\infty} \rho^{i+1} E_t y_{L,t+i}\right] \tag{2}$$

where r is the real interest rate, A_t is the real value of the individual's wealth at the beginning of the period t, $\rho = \frac{1}{1+r}$ is the discount factor, $y_{L,t}$ is real labor income, and E_t is the expectation operator conditional on information available to the individual at time t. Real assets are assumed to follow the process:

$$A_{t+1} = (1+r)A_t + y_{L,t} - c_t. \tag{3}$$

Assuming that expectations are rational, it follows that consumption is a random walk:

$$\Delta c_t = \omega_t \tag{4}$$

where ω_t is white noise (i.e. it is serially uncorrelated)[1]. This version of the permanent income hypothesis has been frequently tested, most notably by Hall (1978), Flavin (1981) and Campbell and Deaton (1989) and has not performed very well. It implies that no past variable should help forecast the change in consumption. Hall found that past values of stock market indices could help forecast the change in consumption, thus violating this version of the PIH, while Flavin found that lagged income had predictive power on the change in consumption. Since she took past values of income to be predictors of current

[1] In practice, (4) also contains a constant, or drift term.

income, this finding was interpreted as suggesting that consumption reacts more heavily to current income than predicted by theory. This is called the excess sensitivity problem.

Finally, Campbell and Deaton found that $\text{var}(\Delta c_t) < \text{var}(\omega_t)$, where ω_t was estimated from a bivariate vector autoregression of savings and labor income. This is called the excess smoothness problem. Despite the terminology, the two findings are not necessarily contradictory as we will see below. In any case, this simple version of the PIH does not seem to be supported by the data and would therefore not be a proper framework for testing Ricardian Equivalence.

An alternative to this simple version was proposed by Atfield, Demery, and Duck (1992) in which partial adjustment to changes in permanent income arise because it takes time for households to adjust their consumption patterns to changes in their permanent income, a possibility discussed by Hall in his original paper. This inertia can be accounted for by fixed contracts or habit formation. This version of the PIH is:

$$c_t = E_{t-n} y_t^p + \sum_{i=0}^{n} \gamma_i E_{t-i} y_t^p \tag{5}$$

where n is the time span required before the full adjustment takes place. We would expect that $0 \le \gamma_0 \le \gamma_1 \le \gamma_2 \le \ldots \le \gamma_n \le 1$, since adjustment to changes in permanent income should be more complete the earlier the change had been expected.

After some algebraic manipulation (see the appendix for details), we can obtain an expression for the change in consumption as a moving average of the innovations in permanent income:

$$\Delta c_t = \sum_{j=0}^{n} \phi_j \omega_{t-j} \tag{6}$$

where the ϕ's are constructed from the γ's, and ω_t represents the revision in permanent income due to the accrual of time t information.

Surprisingly, this version of the PIH is consistent with both excess sensitivity and excess smoothness. Since lagged permanent income shocks are likely correlated with lagged labour income shocks, the model implies that lagged income shocks will affect the current change in consumption, thus explaining the excess sensitivity found by Flavin. On the other hand, excess smoothness is possible since, by taking the variance on both sides of the equation, we get:

$$\text{var}(\Delta c_t) = \text{var}(\omega_t) \bullet \sum_{j=0}^{n} \phi_j^2 \tag{7}$$

If the sum on the right-hand side is less than one, then consumption will be smoother than permanent income. This model of consumption with partial adjustment can thus in principle reconcile the PIH with these stylized facts.

This is not the first model generating a moving average structure for consumption. Ermini (1989) and Holden and Peel (1985) also derived consumption models with moving average terms. Ermini's model was based on a mismatch between the time information about income is received and the time when consumption decisions are made. For their part, Holden and Peel derived a moving average by assuming that some information is available to the agent with a lag. This is an additional rationale for including a moving average term in a consumption function.

3 Ricardian Equivalence: A Theoretical Framework for Testing

The Ricardian Equivalence hypothesis (REH) was first proposed by David Ricardo last century and was popularized 20 years ago by Robert Barro (1974). The REH says that whether the government finances its spending by levying lump-sum taxes or issuing bonds, the private sector remains unaffected. This hypothesis is very similar in flavor to the famous Modigliani-Miller theorem for corporate finance.

The REH is based on stringent assumptions that are unlikely to hold in practice. Nevertheless, even if it does not hold perfectly, it may be a good approximation to the way the world works.

To see how Ricardian equivalence may hold, suppose that an infinitely-lived private agent makes his consumption/saving decisions based on permanent disposable income:

$$y_t^p = r\left[A_t + \sum_{j=0}^{\infty} \rho^{j+1} E_t y_{Lt+j} - \sum_{j=0}^{\infty} \rho^{j+1} E_t T_{t+j}\right] \tag{8}$$

were T_t is taxes payable at time t. All taxes are assumed to be lump-sum. The last term in the definition of permanent income is therefore the expected present value of future tax liabilities.

On the other hand, assuming that the usual transversality condition holds, the government's intertemporal budget constraint is:

$$\sum_{j=0}^{\infty} \rho^{j+1} T_{t+j} = \sum_{j=0}^{\infty} \rho^{j+1} G_{t+j} + B_t \tag{9}$$

where B_t represents government debt at time t and G_t government spending at time t. In words, the present value of future primary surpluses equals the debt. Primary surpluses

are necessary in order to finance interest costs and avoid an unsustainable explosion in the debt. Taking expectations and substituting this expression into the definition of permanent income gives:

$$y_t^p = r\left[A_t + \sum_{j=0}^{\infty} \rho^{j+1} E_t y_{L+j} - \sum_{j=0}^{\infty} \rho^{j+1} E_t G_{t+j} - B_t\right] \tag{10}$$

which already hints at the result, since government bonds are not part of the private sector's assets. A_t is net assets owned by the private sector and is made up of private assets and government debt instruments. Whether the economy is open or closed is irrelevant, since if it is open, the term A_t includes the net foreign assets of the representative agent. The formal ownership of the debt is irrelevant since a government bond owned by foreigners is offset by higher private net foreign assets holdings. Since domestic agents want to increase savings to cover future tax liabilities, they will buy foreign assets, thus creating a private capital outflow. The overall result is the same as if the debt was formally owned domestically: the overall balance of payments is unaffected.

With further algebraic manipulation and assuming that the individual makes her decisions based on the partial adjustment model described previously, the change in consumption can be rewritten as a moving average of the innovations in permanent income:

$$\Delta c_t = \sum_{j=0}^{n} \phi_j \omega_{t-j} \tag{11}$$

where ω_t now includes revisions in expectations about both labor income and government spending. We thus obtain the Ricardian result that the path of the deficit (as measured by changes in the level of debt outstanding) does not affect consumption.

However, it is important to see that this does not mean that government spending on goods and services (G) has no effect on the economy. On the contrary, changes in government spending can have real supply side effects. As pointed out by Baxter and King (1993), a permanent reduction in G reduces government claims on resources, leading to higher private wealth, which implies higher private consumption of both goods and services and of leisure. Higher consumption of leisure implies permanently lower employment and output. This, it should be noted, is a purely supply-side effect that is unrelated to short-term Keynesian aggregate demand effects stemming from nominal rigidities. REH implies that the paths of lump-sum taxes and transfers and debt have no real effects, but leaves open the possibility that the paths of G and distorting taxes may have very pronounced effects. Other supply side effects are possible if G is itself productive.

Ricardian Equivalence is unlikely to hold strictly because the many assumptions that underlie it are unlikely to be satisfied in practice. Agents have neither infinite planning horizons nor access to perfect capital markets. It is true that if parents care for their children and want to leave bequests to pay for future tax liabilities upon their death, then

individuals will have a *de facto* infinite horizon. However, if population growth occurs, some agents will be disconnected from past financing decisions. If a part of the population is liquidity constrained each period, then its consumption pattern will respond more to current income than to permanent income. The use of distortionary taxes causes private agents to react to changes in government debt policy even if Ricardian Equivalence holds, as shown by Trostel (1994) and James (1994).

Now suppose that the representative agent thinks that he or she can somehow completely avoid the future taxes implied by current debt. In this case, government bonds represent net wealth to the population, and permanent income is

$$y_t^p = r\left[A_t + \sum_{j=0}^{\infty} \rho^{j+1} E_t y_{Lt+j} - \sum_{j=0}^{\infty} \rho^{j+1} E_t G_{t+j}\right]. \tag{12}$$

Suppose further, following Haug (1990), that agents assume that government debt will retain its value forever, i.e.

$$E_t \lim_{s\to\infty} (1+r)^{-s} B_s = B_t \tag{13}$$

This can have a few implications. First, it would mean that debt grows at rate r and that interest payments are completely financed out of debt, the famous Ponzi game. This however does not mean that the household expects the government to default on its debt since debt growing at the rate of interest is possible if the taxation capacity of the government increases over time at a rate greater than or equal to r. A household with this belief would treat its holdings of government bonds as net wealth, that is, such a household does not discount its taxes at all. For such a household, the consumption function contains an extra term which is the change in the present value of the amount of debt outstanding (see the appendix):

$$\Delta c_t = \sum_{j=0}^{n} \phi_j \left\{\omega_{t-j} + \left[B_{t-j} - (1+r)B_{t-j-1}\right]\right\} \tag{14}$$

In order to test whether or not government debt is part of the private sector's net wealth, we can suppose that the population is composed of two types of agents, the first consuming according to (11) and a second that considers bonds to be part of wealth. Suppose the proportion of the second type of agents is λ. Then aggregate consumption is given by:

$$\Delta C_t = \sum_{j=0}^{n} \phi_j \left\{\omega_{t-j} + \lambda\left[B_{t-j} - (1+r)B_{t-j-1}\right]\right\}. \tag{15}$$

A test of Ricardian Equivalence can be performed by testing whether λ is 0. This is done in section 6. Note however, that $\lambda = 0$ is a necessary, but not sufficient condition for Ricardian Equivalence to hold. Any test which rejects this hypothesis rejects REH, but failing to reject it does not necessarily mean that REH is true.

Before turning to the test, however, I will briefly summarize other studies that have been done. It will be easier to follow this brief review now that some terminology has been introduced. I will then turn to the issue of estimating the market value of government debt in order to be able to estimate equation (15) before presenting my empirical results.

4 Summary of Previous Studies

The literature on Ricardian Equivalence is extensive and diverse. This review will be brief since a good recent survey is available in Seater (1993). I will only summarize the various approaches and their conclusions. The tests can be divided into two large groups, consumption studies and interest rate studies, and some smaller ones which involve comparison of growth rates, exchange rates or the current account.

Most studies in the first group use a variant of the life-cycle-permanent income hypothesis, add some elements of the government budget and test their significance. The estimation techniques vary as widely as the variables included, the time span covered, and the treatment of endogeneity and non-stationarity. These studies generally cannot reject Ricardian Equivalence, although there are a few exceptions.

I will summarize only three consumption studies. The first serious attempt at testing the REH was by Feldstein (1982). He based his test on the following equation:

$$C_t = \alpha_0 + \alpha_1 Y_t + \alpha_2 W_t + \alpha_3 SSW_t + \alpha_4 G_t + \alpha_5 T_t + \alpha_6 TR_t + \alpha_7 D_t + e_t \qquad (16)$$

where Y_t is current income, W_t is the market value of private wealth at the beginning of the period, SSW_t is a measure of future Social Security benefits, G_t is total government purchases, T_t is total tax revenues, TR_t is transfers to individuals, D_t is net total government debt at the beginning of the period measured at par, and e_t is a residual. Feldstein correctly argues that Ricardian Equivalence implies that $\alpha_4 < 0$, $\alpha_3 = \alpha_5 = \alpha_6 = 0$, and that $\alpha_2 = -\alpha_7$. He estimated this equation using both OLS and two-stage least squares. With OLS, only $\alpha_6 = 0$ could be rejected and with 2SLS, he also could not reject $\alpha_4 = 0$. He did not report any joint test of all the hypotheses implied by Ricardian Equivalence. Overall, his results were mildly contrary to REH.

Seater and Mariano (1985), however, have shown that the Feldstein study contained some econometric flaws. Some of the instruments used in the 2SLS estimation were themselves endogenous. Secondly, debt should have been valued at market rather than at par. With a correct set of instruments, only $\alpha_6 = 0$ could be rejected. The inclusion of cyclical indicators and marginal tax rates changes this conclusion. Feldstein's study thus suffers from a missing variable problem. Data stationarity was also not analyzed.

Seater and Mariano (1985) estimated a consumption function closer in spirit to a permanent income specification:

$$C_t = \alpha_0 + \alpha_1 Y_t^* + \alpha_2 (Y_t - Y_t^*) + \alpha_3 G_t^* + \alpha_4 (G_t - G_t^*) + \alpha_5 AMTR_t + \alpha_6 RS_t + \alpha_7 RL_t + \alpha_8 T_t + \alpha_9 TR_t + \alpha_{10} D_t + \alpha_{11} SSW_t + e_t \quad (17)$$

where Y^* is permanent income, Y is current income, G^* is permanent government purchases, G is current government purchases. AMTR is a measure of marginal tax rates obtained from Seater (1985), RS is a short-term after-tax interest rate, RL is a long-term after-tax interest rate, T is tax revenue, TR is transfers to individuals, D is the market value of government debt, and SSW is Social Security wealth. The two permanent variables were constructed using the Beveridge and Nelson (1981) decomposition which is based on fitting an ARMA model to the data.

The 2SLS estimates could not reject the hypotheses that α_8 to α_{11} were all 0. Moreover, the coefficient on transitory income was statistically significant, implying that liquidity constraints, if they exist, are not of a type that would invalidate Ricardian Equivalence.

Evans and Hasan (1994) used Blanchard's (1985) model with uncertain lifetime to test Ricardian Equivalence for Canada. Assuming exponential utility, they obtained a reduced form consumption function of the form

$$\Delta c_t = \alpha_0 + \alpha_1 A_{t-1} + \mu_t \quad (18)$$

where A_t is the real net worth of the private sector. Using yearly data over the period 1962-1986, they could not reject that α_1 was 0 using either OLS or 2SLS. Thus, they could not reject Ricardian equivalence for Canada.

Finally, a last class of consumption-based tests uses Euler equations (first-order condition arising from the consumer optimization problem) to test the validity of Ricardian Equivalence. The main study, by Evans and Hasan, used Blanchard's (1985) uncertain lifetimes framework. Most studies in this category cannot reject Ricardian Equivalence.

The second large group of studies seeks to determine whether interest rates are pushed higher by large government deficits and debt. With Ricardian Equivalence, an increase in bonds issuance would be counterbalanced by an increase in the demand for bonds by consumers, thus leaving interest rates unaffected. The main problem with the applicability of these studies for a small open economy is that interest rates may be largely determined abroad, hence the tests would have little power. It is thus not surprising that these tests have not been used with Canadian data.

For a small open economy, it is possible to carry out alternative tests using the current account or the exchange rate. In the absence of REH, a budget deficit would lead to a capital inflow, a current account deficit, and an appreciating exchange rate. Evans (1988c) found that budget deficits had no impact on the current accounts of Canada, France, Germany, the United Kingdom, and the United States.

On balance, the empirical evidence cannot reject Ricardian Equivalence. This, as discussed before, does not necessarily mean that Ricardian Equivalence is strictly true. However, it does suggest that it is a good approximation.

5 Construction of Market Value Series

In order to estimate the future tax liabilities implied by government debt, it is necessary to determine its market value. Market value series for Canadian federal debt can be found in Cox and Haslag (1987) and in Boothe and Reid (1987). Cox and Haslag estimate the appropriate aggregate, debt held by the private sector, but the series does not extend beyond 1984 and does not include the provinces. In view of these shortcomings, a new series had to be estimated.

The par value of debt was corrected using a simple but clever method suggested by Butkiewicz (1983) for the United States. This method is based on a formula relating par to market values:

$$MV = \frac{1+nc}{1+nr} PV \tag{19}$$

where MV is market value, PV is par value, n is the term to maturity, c is the coupon rate, and r is the market yield. I estimated this ratio for the federal government marketable debt held by the public and used it to convert all appropriate debt evaluated at par.

This formula was operationalized by using the average length of marketable debt outstanding held by the general public for n and the market yield of an issue of average maturity for r[2]. The average coupon rate was obtained by taking the interest paid on treasury bills and bonds and dividing it by the amount outstanding. Unfortunately, these data are only available from 1980. Earlier estimates were obtained by combining Cox and Haslag's estimates of the ratio of par to market with the average term to maturity of total federal marketable debt to solve for the implicit coupon rate. It was assumed that the average coupon rate on debt held by the public was similar to the average coupon rate on the total debt.

In order to test the performance of this method. I estimated the ratio of par to market for gross federal debt between 1980 and 1984 and compared it with the series in Cox and Haslag. The correlation between the two series over this period was 0.9256, between implied debt levels 0.9957, and between implied debt differences 0.9991. Unfortunately, the correlation between the coupon rate series was only 0.3330. For comparison, Butkiewicz found a correlation of 0.911 for the ratios and 0.998 for the levels using annual data in the United States over the 1958-1975 period.

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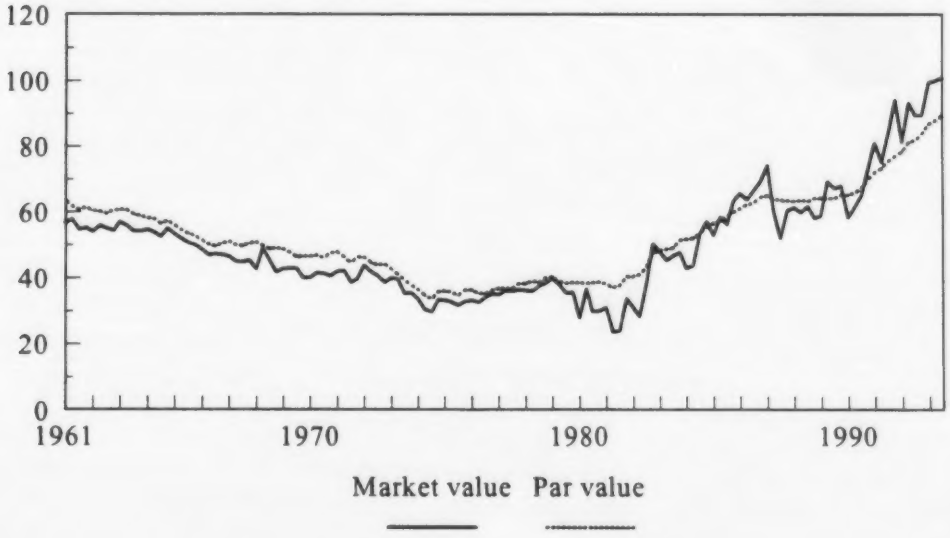
[2] I would like to thank George Naft from the Securities Department at the Bank of Canada for providing me with access to this data.

The first decade or so of data was adversely affected by the fact that there were relatively few issues of bonds. Because of this, it was sometimes necessary to take the yield of an issue that matured more than a year away from the average issue. This, and the poor proxy for the coupon rate cast doubt on the reliability of the early part of the series which was estimated from 1961.

Domestic liabilities and foreign debt of the PLH sector were converted to market value using the federal market-to-par ratios. This assumes that all levels of governments have a similar term structure of debt.

Chart 1 shows the two series as a proportion of GDP. They follow a roughly similar pattern, with debt trading at a discount for most of the period with the exception of the last three years. The market value series is much more volatile due to changes in interest rates. When interest rates rise, the ratio of market to par falls and vice-versa. The correlation between the levels of debt held by the public at par and at market is 0.9912 due to a common trend. Once differenced, the correlation falls to 0.4568, signaling a significant gain in converting the data.

Chart 1
Total Government Gross Debt
at Market and Par Values
Percent of GDP



6 Empirical results

As derived in section 3, the test of Ricardian Equivalence carried out in this paper involves estimating equation 15. I included a constant in the function to allow for drift, which yielded the estimated equation:

$$\Delta C_t = \pi + \sum_{j=0}^{n} \phi_j \left\{ \omega_{t-j} + \lambda \left[B_{t-j} - (1+r) B_{t-j-1} \right] \right\} \tag{20}$$

where C_t is real per capita consumption, B_t is real per capita government debt evaluated at market value, and r is the appropriate market interest rate. After a brief description of the variables, the estimation methodology will be described and the results presented.

Consumption was defined as expenditures on services and nondurable goods at 1986 prices in accordance with most consumption studies. Data on government debt was described in the previous section. Gross debt was used since the valuation to market value of assets that could be sold to pay off the debt is a formidable task that is fraught with many difficulties. B_t was therefore per capita gross debt deflated by the CPI.

For the interest rate, the arithmetic mean of the difference between the effective rate on personal term deposits and CPI inflation over the 1970 to 1993 period was used. This gave an interest rate of 0.9959 percent per quarter, very close to the 1 percent used in many studies. The results did not depend on this value. Values as high as 2 percent per quarter did not materially change the results.

The consumption function (20) had two main advantages from an estimation standpoint. First, although it was based on the permanent income hypothesis, no estimate of permanent income was required. The innovations in permanent income were derived from the estimation as the residuals. Secondly, the equation was in first differences, thus avoiding problems related to nonstationarity and the low power of unit root tests.

The estimation of (20) could not be carried out using least squares because minimizing the sum of squares would lead to setting ϕ_0 to $\pm\infty$. The Kalman filter approach of Atfield, Demery and Duck (1992) is therefore used (see also Harvey (1981)). The Kalman filter is a set of equations which allows a set of estimates to be updated once new information becomes available (see the appendix for its formulation). Using this filter, it is possible to generate prediction errors and construct their likelihood. Maximization of this likelihood leads to unconditional likelihood estimates. This method allows for heteroskedasticity since the variance of the prediction errors are not constrained to be equal over the whole sample. As starting values, I used the results of Atfield, Demery, and Duck for the United States.

The sample period ranged from the first quarter of 1971 to the last quarter of 1993. The model exhibited some instability when data from the 1960's was included. However, the conclusions were not materially affected by the sample choice.

Table 1

Regression results
Sample: 1970:1-1993:4
(standard errors in parentheses for estimates, p-values for test statistics)

Equation	π	γ_0	γ_1	γ_2	λ	Box-Ljung (12 lags)	Stability test	Orthogonality test
6	0.0326 (0.0067)	0.7970 (0.1027)	0.7833 (0.0794)	0.8669 (0.0663)	--	8.7255 (0.4630)	4.4142 (0.4914)	10.225 (0.4210)
20	0.0325 (0.0067)	0.7964 (0.1022)	0.7833 (0.0798)	0.8680 (0.0665)	0.0019 (0.0074)	8.7350 (0.4621)	1.454 (0.9183)	10.150 (0.4275)
6 (U.S.)	0.0382 (0.0102)	0.5340 (0.0634)	0.7024 (0.0660)	0.7954 (0.0367)	--	12.205 (0.2020)	4.338 (0.3622)	5.8241 (0.3237)

The results of the model with and without the inclusion of the debt term are presented in Table 1. Several features are notable. First, the coefficient on the debt term is not significantly different from 0, suggesting that Ricardian Equivalence cannot be rejected. Secondly, the point estimate of γ_0 should be less than γ_1. However, the standard errors show that γ_1 could be as low as 0.6 and still be within the 95 percent confidence interval. The high value for the first parameter is peculiar to Canada. The results of the same regression for the United States are presented in the third row of the table. These conform to priors. Finally, only three lags were necessary before the coefficient became insignificantly different from 1 both for Canada and the U.S.. Atfield, Demery, and Duck required 4 for the U.S. and 5 for the U.K..

The measure of excess smoothness implied by the estimates in the table for the second equation is about 65 percent. This is fairly high in comparison to the 39 percent found by Atfield, Demery and Duck for the United States and reflects the high estimated value for γ_0.

Various diagnostic checks were carried out on the model. To test for autocorrelation, I calculated the Box-Ljung statistic for each of the first 36 lags. I report its value for 12 lags, but the smallest p-value among the first 36 lags was 24 percent and occurs at lag 26. The statistic is distributed as chi-square with degrees of freedom equal to the number of lags less the number of ARMA parameters estimated (3 in this case).

To test the stability of the parameters, two subregressions using the first quarter of 1982 as a breaking point were run. Twice the difference of the likelihood functions was distributed as chi-square with 5 degrees of freedom since all 5 parameters were allowed to vary over the two subsamples. Due to the large standard errors, the hypothesis of structural change could not be rejected, although the point estimates varied greatly between the two subperiods (for example, the estimate of γ_0 was 0.97 with a standard error of 0.21 in the first subsample and 0.59 with a standard error of 0.14 in the second).

To test the assumption that no information prior to the current period should help forecast the change in consumption, I included 5 lagged values of the changes in consumption and personal income and tested their significance. However, this orthogonality test presented some difficulties. The presence of both autoregressive and moving average components caused the algorithm to fail to converge for this sample, although it converged over some other samples. This arose because some of the roots of the AR and MA processes nearly cancelled each other out, leading to a lack of identification. This problem was resolved by inverting the original MA process and estimating it as a restricted AR process. Let the original model be given by:

$$\Delta C_t = \pi + \phi(L)\{\omega_t + \lambda[B_t - (1+r)B_{t-1}]\} \tag{21}$$

where $\phi(L) = \phi_0 + \phi_1 L + \phi_2 L^2 + \phi_3 L^3$ is a polynomial in the lag operator. Dividing each side by this polynomial and multiplying by ϕ_0, we obtain the same model expressed as an infinite autoregressive process:

$$\alpha(L)\Delta C_t = \mu + \kappa[B_t - (1+r)B_{t-1}] + \varepsilon_t \tag{22}$$

where $\alpha(L) = 1 - \alpha_1 L - \alpha_2 L^2 - \alpha_3 L^3 - \ldots$, $\mu = \frac{\pi\phi_0}{\phi(L)}$; $\kappa = \frac{\lambda\phi_0}{\phi(L)}$, and $\varepsilon_t = \frac{\phi_0\omega_t}{\phi(L)}$.
The parameters of the autoregressive polynomial are restricted as follows:

$$\alpha_1 = \frac{\phi_1}{\phi_0}$$

$$\alpha_2 = \frac{\phi_1}{\phi_0}\alpha_1 + \frac{\phi_2}{\phi_0}$$

$$\alpha_3 = \frac{\phi_1}{\phi_0}\alpha_2 + \frac{\phi_2}{\phi_0}\alpha_1 + \frac{\phi_3}{\phi_0}$$

$$\alpha_j = \frac{\phi_1}{\phi_0}\alpha_{j-1} + \frac{\phi_2}{\phi_0}\alpha_{j-2} + \frac{\phi_3}{\phi_0}\alpha_{j-3} \qquad \text{for } j \geq 4.$$

The correlograms indicated that no partial autocorrelation was significant after t-3 and the Akaike Information Criterion (AIC) reached a minimum at t-3 as well. Therefore, I estimated a restricted AR(3) model to carry out the orthogonality test. The residuals showed no serial correlation, and the likelihood of this model was very similar to that obtained with the MA model.

The orthogonality test was carried out by adding 5 lags of the change in consumption and change in personal disposable income. Only the 5th lag of the change in personal disposable income was significant at the 5 per cent level and the likelihood ratio test could

not reject the hypothesis that all the lagged values had a zero coefficient. A multicollinearity problem could, however, be created by including lagged disposable income in the same regression as the change in debt, since a tax cut would imply higher debt and higher disposable income. For the United States, I only included 5 lagged values of the change in consumption for this test.

Overall, the consumption model with partial adjustment was quite robust and performed well for Canadian data and suggested that Ricardian Equivalence cannot be rejected.

7 Conclusion

This paper has estimated a generalized permanent income model of consumption to test the hypothesis of Ricardian Equivalence for Canada. The results suggest that the PIH model is consistent with the stylized facts for consumption, and that Ricardian Equivalence is a reasonable approximation of the response of private households to government deficits. The latter conclusion confirms the findings of a wide range of other studies. It is possible, however, that the private savings offset is slightly less than 100 per cent. Many theoretical objections, such as the absence of full intergenerational altruism, lead to the view that absolute Ricardianism is improbable. The econometric evidence cannot distinguish between absolute and near Ricardian equivalence. Under near Ricardianism, changes in the government debt may have real effects. In addition, while not studied in this paper, the path of distorting taxes may affect saving and labour supply decisions. This, rather than a substantial deviation from Ricardian equivalence, is likely the main channel through which government debt affects the real economy.

Appendix

Derivation of (4)

Substituting the definition of A_t in the definition of permanent income allows it to be expressed as:

$$y_t^p = (1+r)y_{t-1}^p - rc_{t-1} + \omega_t$$

from which it follows that:

$$\Delta E_t y_t^p = \omega_t$$

where $\Delta E_t y_t^p = E_t y_t^p - E_{t-1} y_t^p$.

Substituting this into the assumed consumption behavior (equation (1)) yicids equation (4):

$$c_t = y_t^p$$

Derivation of (6)

Once again, permanent income can be expressed as:

$$y_t^p = (1+r)y_{t-1}^p - rc_{t-1} + \omega_t$$

from which it follows that:

$$\Delta E_t y_t^p = \omega_t$$

$$\begin{aligned}\Delta E_{t-1} y_t^p &= \Delta E_{t-1}\left[(1+r)y_{t-1}^p - rc_{t-1} + \omega_t\right] \\ &= \Delta E_{t-1}\left[(1+r) - r\gamma_0\right]y_{t-1}^p \\ &= \left[(1+r) - r\gamma_0\right]\omega_{t-1}\end{aligned}$$

$$\begin{aligned}\Delta E_{t-2} y_t^p &= \Delta E_{t-2}\left[(1+r)y_{t-1}^p - rc_{t-1} + \omega_t\right] \\ &= \Delta E_{t-2}\left[(1+r) - r\gamma_1\right]y_{t-1}^p \\ &= \left[1 + r(1-\gamma_1)\right]\Delta E_{t-2} y_{t-1}^p \\ &= \left[1 + r(1-\gamma_1)\right]\left[1 + r(1-\gamma_0)\right]\omega_{t-2}\end{aligned}$$

and in general,

$$\Delta E_{t-j} y_t^p = \left[\prod_{i=0}^{j-2} \xi_i\right] \omega_{t-j} \text{ where } \xi_i = [1 + r(1-\gamma_i)]$$

Using the hypothesized process for consumption (equation (5), we get that the change in consumption is given by

$$\Delta c_t = \gamma_0 \omega_t + (\gamma_1 \xi_0 - \gamma_0)\omega_{t-1} + (\gamma_2 \xi_1 - \gamma_1)\xi_0 \omega_{t-2} + \ldots + \left\{(\gamma_{n-1}\xi_{n-2} - \gamma_{n-2})\left[\prod_{i=0}^{n-3} \xi_i\right]\right\}\omega_{t-n+1} + \left\{(\xi_{n-1} - \gamma_{n-1})\left[\prod_{i=0}^{n-2} \xi_i\right]\right\}\omega_{t-n}$$

Relabelling, we can see that the change in consumption is a moving average of the innovation in permanent income:

$$\Delta c_t = \sum_{j=0}^{n} \phi_j \omega_{t-j}$$

which is equation 6.

Derivation of (14)

Permanent income can now be rewritten as:

$$y_t^p = (1+r)y_{t-1}^p - rc_{t-1} + E_t \lim_{s\to\infty}(1+r)^{-s} B_s - (1+r)E_{t-1} \lim_{s\to\infty}(1+r)^{-s} B_s + \omega_t$$

Previously, the two limit terms were 0, but with our assumption about the behavior of private agents, these terms are now $B_t - (1+r)B_{t-1}$. Going through the same steps as before, we get:

$$\Delta c_t = \sum_{j=0}^{n} \phi_j \left\{\omega_{t-j} + \left[B_{t-j} - (1+r)B_{t-j-1}\right]\right\}$$

which is equation 14.

The Kalman filter

This section gives a brief overview of the Kalman filter. For further reference, the reader is invited to read Harvey (1981) chapter 4.

The Kalman filter is applied to a model of the form:

$$y_t = Z_t\alpha_t + S_t\xi_t$$
$$\alpha_t = T_t\alpha_{t-1} + R_t\eta_t$$

where Z_t, S_t, T_t, and R_t are all fixed matrices and ξ_t and η_t are vectors of disturbances with respective covariance matrices H_t and Q_t. α_t is called the state vector. The first equation is often referred to as the measurement or plant equation and the second as the transition or state equation.

The Kalman filter starts from some initial guess of the state vector and updates it recursively through the sample. Let a_t be the "best" estimate of the state vector based on all information up to time t with a variance matrix P_t. Also, let the "^" quantities be the best estimates of these based on past information only. The difference between the two is due only to the accrual of new information in the system. The Kalman filter therefore consists of a set of prediction equations:

$$\hat{a}_t = T_t a_{t-1}$$
$$\hat{P}_t = T_t P_{t-1} T_t' + R_t Q_t R_t'$$

and a set of updating equations:

$$a_t = \hat{a}_t + \hat{P}_t Z_t' F_t^{-1}(y_t - Z_t\hat{a}_t)$$
$$P_t = \hat{P}_t - \hat{P}_t Z_t' F_t^{-1} Z_t \hat{P}_t$$
where $F_t = Z_t\hat{P}_t Z_t' + S_t H_t S_t'$

The updating equations basically take the "best" predictor and correct it for the new information that has been obtained. These formulas can be used from any valid staring value for a_0 and P_0.

The term in brackets in the first updating equation is called the prediction error. This prediction error has variance matrix F_t, and therefore we can construct its likelihood.

The advantage of this method for the current problem stems from the fact that y_t is a 1x1 vector so that the likelihood does not require the inversion of any matrix. To see how the current problem can be expressed in a form suitable to apply the Kalman filter, define the state vector as:

$$\alpha_t = \begin{pmatrix} \phi_0\omega_t + \phi_1\omega_{t-1} + \phi_2\omega_{t-2} + \phi_3\omega_{t-3} \\ \phi_1\omega_t + \phi_2\omega_{t-1} + \phi_3\omega_{t-2} \\ \phi_2\omega_t + \phi_3\omega_{t-1} \\ \phi_3\omega_t \end{pmatrix}$$

and the T_t and R_t matrices in the transition equation are constant across time and given by:

$$T_t = \begin{pmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \text{ and } R_t = \begin{pmatrix} \phi_0 \\ \phi_1 \\ \phi_2 \\ \phi_3 \end{pmatrix}$$

The measurement equation is $\Delta c_t = \pi + Z_t\alpha_t$ where Z_t is a vector which has a 1 as the first element and zeros elsewhere. This vector picks up the first element of the state vector.

The original a_t was then a vector of zeros and the original P_t was $E(\alpha_t\alpha_t')$ evaluated at the starting values for the system. The full likelihood is:

$$LLF = -\frac{T}{2}\ln(2\pi) - \frac{T}{2}\ln\sigma^2 - \frac{1}{2}\sum_{t=1}^{T}\ln f_t - \frac{1}{2\sigma^2}\sum_{t=1}^{T}\frac{v_t^2}{f_t}$$

where v_t is the prediction error and is equal to $\Delta C_t - \pi - Z_t\alpha_t$. Concentrating the likelihood by first maximizing with respect to σ^2 leads to a likelihood of a simple form:

$$LLF = -\frac{T}{2}[\ln(2\pi)+1] - \frac{T}{2}\ln\left[\frac{1}{T}\sum_{t=1}^{T}\frac{v_t^2}{f_t}\right] - \frac{1}{2}\sum_{t=1}^{T}\ln f_t$$

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